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Automated Decision-Making with TOPSIS for Water Analysis

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Abstract. This paper aims to present a new application of TOPSIS with an automated decision-making process for the analysis of drinking water. For this purpose, the algorithm was modified with a fuzzy disjunction, and the maximal output values were set to one. The properties of drinking water, such as total dissolved solids, hardness, electrical conductivity, and cost, were the criteria analyzed in this study. These criteria were analyzed with unmodified and modified algorithms. Therefore, the modified TOPSIS was also used to optimize the parameters of the candidates. The appearance of the value of 1.0 in the algorithm's output was due to the confusion of an individual's categories of drinking water and undrinkable water. The advantage of this investigation was that, for the first time, it allowed automated decision-making to detect the drinking water in different samples and analyze them according to their characteristics. This would be important in developing new technologies for detecting and analyzing drinking water in the environment. The results of this paper can be applied in materials sciences and engineering.

Keywords: TOPSIS, water, automated decision-making, computational engineering, process innovation.

1 Introduction

Drinking water is essential for human life and is in high demand in many countries [1-3]. Many people worldwide do not have access to safe drinking water [4]. The chemistry and toxicology of the chemicals in underground water can determine their characteristics for performing essential drinking water production processes [5].

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is an appropriate decision-making method with diverse applications in science and engineering [6-10]. The candidates' ranking in this method is performed according to their distances from ideal solutions and their closeness coefficients [11-15].

The characteristics of drinking water, such as its total dissolved solids, hardness, electrical conductivity, and cost, must be analyzed [16-19]. The modified version of the TOPSIS method can help determine which water sample would be more appropriate according to its rank.

Moreover, the automated decision-making process must be performed with the modified algorithm. This would make the distinction between drinking water and non-consumable water. This analysis would help the next generation of robots distinguish and analyze different drinking water samples without human intervention. As the amount of drinking water can decrease during the next decades on the planet, researching this material on other planets would be essential for human survival.

Demarcator theory is a theory according to which three characteristics, called the demarcators, are found in the category members for their distinction from the members of other categories. The strong and weak demarcators have an impact on this distinction.

However, the marginal demarcators do not positively affect this distinction, but their consideration leads to category confusion and inconsistency in epistemic beliefs [8, 20, 21].

According to the demarcator theory, the total dissolved solids in samples is their strong demarcator that impacts the distinction of drinking water from undrinkable water. In contrast, hardness and electrical conductivity are the weak demarcators that have less effect for this distinction. The transparency and amount of water and its cost cannot affect the importance of drinking water and undrinkable water. These marginal demarcators do not help humans distinguish the members of these categories.

This work aimed to optimize the drinking and undrinkable water samples with unmodified and modified TOPSIS methods.

For this purpose, the following tasks were performed:

1) optimization of water samples with unmodified TOPSIS;

2) modification of TOPSIS with the Łukasiewicz fuzzy disjunction;

3) optimization of water samples with modified TOPSIS.

The prediction, detection, and analysis of drinking water samples with modified TOPSIS with an automated decision-making process have not been performed previously. The results of this paper can find their applications in science and engineering.

2 Research Methodology

2.1 TOPSIS method

The TOPSIS code in Python is available on the GitHub website https://github.com/Glitchfix/TOPSIS-Python/blob/master/topsis.py. It was used for the optimization of parameters in this paper.

The main steps of this code were described previously [12].

2.2 Modified TOPSIS

The modified TOPSIS, including the Łukasiewicz fuzzy disjunction developed in new software, was used in this paper as described previously [8]. In the data analysis with the modified algorithm, the members of two categories of drinking water (candidates C1 and C2) and undrinkable water (C3, C4, and C5) were considered.

The category confusion due to humans' inappropriate consideration of the criteria that led to the inconsistency of their epistemic beliefs was analyzed as explained previously [8]. In the second series of analyses with the modified algorithm, turbidity as a marginal demarcator of water, which was a cost criterion, was added to the evaluation matrix. The categories confusion due to the consideration of this criterion as a profit criterion was evaluated with the fuzzy disjunction. This was because individuals mistakenly considered it a characteristic that positively distinguished the two water categories. The maximal value of 1.0, according to the Łukasiewicz fuzzy disjunction was observed in the evaluation matrix in the output.

3 Results and discussion

The first series of results were obtained with the unmodified TOPSIS algorithm.

Table 1 shows the evaluation matrix of water samples as candidates and their criteria.

Table 1 – Evaluation matrix of water samples as candidates and their criteria

Candidates/ Criteria	Total dissolved solids	Hardness	Electrical conductivity	Cost
C_1	very low	very low	low	high
C_2	very low	very low	low	medium
C_3	medium	medium	medium	low
C_4	medium	medium	medium	medium
C_5	high	high	high	medium

Tables 2 and 3 show the matrices of triangular fuzzy data and their mean values, respectively.

Tables 4 and 5 show the matrix of the weights applied for each criterion of the water samples and the criteria matrix, respectively.

Table 6 shows the distances between the best and worst alternatives, the similarity coefficients, and rankings for water samples.

Table 2 – Matrix of triangular fuzzy data

Candidates/ Criteria	Total dissolved solids	Hardness	Electrical conductivity	Cost
C_1	0.1, 0.2, 0.3	0.1, 0.2, 0.3	0.2, 0.3, 0.4	0.7, 0.8, 0.9
C_2	0.1, 0.2, 0.3	0.1, 0.2, 0.3	0.2, 0.3, 0.4	0.4, 0.5, 0.6
C_3	0.4, 0.5, 0.6	0.4, 0.5, 0.6	0.4, 0.5, 0.6	0.2, 0.3, 0.4
C_4	0.4, 0.5, 0.6	0.4, 0.5, 0.6	0.4, 0.5, 0.6	0.4, 0.5, 0.6
C_5	0.7, 0.8, 0.9	0.7, 0.8, 0.9	0.7, 0.8, 0.9	0.4, 0.5, 0.6

Table 3 – Matrix of the mean values of triangular fuzzy data

Candidates/ Criteria	Total dissolved solids	Hardness	Electrical conductivity	Cost
C_1	0.2	0.2	0.3	0.8
C_2	0.2	0.2	0.3	0.5
C_3	0.5	0.5	0.5	0.3
C_4	0.5	0.5	0.5	0.5
C_5	0.8	0.8	0.8	0.5

Table 4 – Weights applied for each criterion of water samples

Alternatives/ Values	Total dissolved solids	Hardness	Electrical conductivity	Cost
$C_1 – C_5$	0.5	0.5	0.5	0.5

Table 5 – Criteria matrix for water samples

Alternatives/ Values	Total dissolved solids	Hardness	Electrical conductivity	Cost
$C_1 – C_5$	false	false	false	false

Table 6 – The distances from the best and worst alternatives (d_i^* and d_i^-), the similarity coefficients (CC_i)and rankings for water samples

Candidates	d_i^*	d_i^-	CC_i	Ranking
C_1	0.1027	0.2207	0.6824	2
C_2	0.0411	0.2292	0.8479	1
C_3	0.1054	0.1550	0.5952	3
C_4	0.1132	0.1315	0.5374	4
C_5	0.2245	0.0617	0.2154	5

The second series of results were obtained with the modified TOPSIS algorithm. The Łukasiewicz fuzzy disjunction was applied to allow only the values equal to or below 1.0 to appear in the output.

Table 7 shows the evaluation matrix of water samples as candidates and their criteria.

Tables 8 and 9 show the matrices of triangular fuzzy data and their mean values, respectively.

Table 7 – Evaluation matrix of water samples as candidates and their criteria

Candi-dates/ Criteria	Total dissolved solids	Hardness	Electrical conduc-tivity	Cost	Turbidity
C_1	very low	very low	low	high	very low
C_2	very low	very low	low	medium	very low
C_3	medium	medium	medium	low	medium
C_4	medium	medium	medium	medium	medium
C_5	high	high	high	medium	medium

Table 8 – Matrix of triangular fuzzy data

Candi-dates/ Criteria	Total dissolved solids	Hardness	Electrical conduc-tivity	Cost	Turbidity
C_1	0.1,0.2,0.3	0.1,0.2,0.3	0.2,0.3,0.4	0.7,0.8,0.9	0.1,0.2,0.3
C_2	0.1,0.2,0.3	0.1,0.2,0.3	0.2,0.3,0.4	0.4,0.5,0.6	0.1,0.2,0.3
C_3	0.4,0.5,0.6	0.4,0.5,0.6	0.4,0.5,0.6	0.2,0.3,0.4	0.4,0.5,0.6
C_4	0.4,0.5,0.6	0.4,0.5,0.6	0.4,0.5,0.6	0.4,0.5,0.6	0.4,0.5,0.6
C_5	0.7,0.8,0.9	0.7,0.8,0.9	0.7,0.8,0.9	0.4,0.5,0.6	0.4,0.5,0.6

Table 9 – Matrix of the mean values of triangular fuzzy data

Candi-dates/Criteria	Total dissolved solids	Hardness	Electrical conductivi-ty	Cost	Turbidity
C_1	0.2	0.2	0.3	0.8	0.2
C_2	0.2	0.2	0.3	0.5	0.2
C_3	0.5	0.5	0.5	0.3	0.5
C_4	0.5	0.5	0.5	0.5	0.5
C_5	0.8	0.8	0.8	0.5	1.0

In Table 9, in comparison with table 3, the maximal value of 1.0 was observed for the last alternative due to the Łukasiewicz fuzzy disjunction, which showed the confusion of both drinking categories and undrinkable water samples by an individual.

Tables 10 and 11 show the matrix of the weights applied for each criterion of the water samples and the criteria matrix, respectively.

Table 12 shows the distances between the best and worst alternatives, the similarity coefficients, and rankings for water samples.

Table 10 – Weights applied for each criterion of water samples

Alterna-tives/ Values	Total dissolved solids	Hardness	Electrical conduc-tivity	Cost	Turbidity
$C_1 – C_5$	0.5	0.5	0.5	0.5	0.5

Table 11 – Criteria matrix for water samples

Alterna-tives/Values	Total dis-solved solids	Hardness	Electrical conductivi-ty	Cost	Turbidity
$C_1 – C_5$	false	false	false	false	true

Table 12 – The distances from the best and worst alternatives (d_i^* and d_i^-), the similarity coefficients (CC_i), and rankings for water samples

Candidates	d_i^*	d_i^-	CC_i	Ranking
C_1	0.1515	0.1766	0.5382	2
C_2	0.1315	0.1833	0.5824	1
C_3	0.1159	0.1329	0.5341	3
C_4	0.1205	0.1155	0.4894	4
C_5	0.1796	0.1365	0.4318	5

The comparison of the obtained results revealed several important issues. The drinking water samples, candidates 1 and 2, were ranked in the first two positions, whereas undrinkable water samples were ranked in the three last positions.

Moreover, the cost impacts the ranking of drinking water samples, and the candidate with a lower cost, the second candidate, was ranked in the first position. The candidates' distances from the best and worst alternatives and their similarity coefficients were different with the unmodified and modified algorithms.

However, the same rankings were obtained in both analyses. The appearance of the value of 1.0 in the algorithm's output was due to the confusion of an individual's categories of drinking water and undrinkable water. This could be attributed to his inconsistency in epistemic beliefs.

Previously, the characteristics of several materials were investigated [22-26]. Moreover, new materials have been explored for their diverse applications in sciences and engineering [27-30]. It has been shown that nanoparticles [31, 32], polymers [33-36], and nanocomposites [37] could be used for water treatment. TOPSIS has been used for the selection of polymers [38-41], nanomaterials [42-44], and machine process parameters [45]. It has been shown to be efficient for optimizing analytic procedures and normalization methods [46, 47], and materials [48-52].

Although TOPSIS has been used to optimize some materials, its modified version with the Łukasiewicz fuzzy disjunction has not previously been used for their optimization. In other words, none of these previous studies has been done with the automated decision-making process with modified TOPSIS. To optimize these materials, it would be required to perform the automated decision-making process with the modified TOPSIS as presented in this paper.

More investigations are needed to improve the analysis method of drinking and undrinkable water samples with the TOPSIS algorithm. In the next step, the water samples with different concentrations of ions will be investigated.

4 Conclusions

The article aims to explain the analysis results of drinking and undrinkable water samples with an automated decision-making process. The tasks of this study were performed with unmodified and modified TOPSIS algorithms. The modified TOPSIS method was obtained by adding the Łukasiewicz fuzzy disjunction to the algorithm. For this purpose, the maximal values of the membership degrees were set to one.

To perform the analysis, the modified TOPSIS algorithm with this fuzzy disjunction was used, giving comparable results to the unmodified algorithm.

Although the distances from the best and worst alternatives and similarity coefficients differed with the unmodified and modified algorithms, the same rankings were obtained in both analyses.

The appearance of the value of 1.0 in the output of the algorithm, due to the confusion of the categories of drinking water and undrinkable water by the individual, could be attributed to his inconsistency in epistemic beliefs.

Overall, the research presents a new application of TOPSIS for predicting and detecting water samples that could be applied in sciences and engineering.

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